Lat 40.19855 Lon -121.16427

Forest Health Protection

Pacific Southwest Region

Northeastern California Shared Service Area

Date: August 21, 2018
File Code: 3420

To: District Ranger, Almanor Ranger District, Lassen National Forest

Subject: Evaluation of stand conditions in the West Shore forest health project (FHP Report NE18-11)

At the request of Crystal Danheiser, Forester, Almanor Ranger District, Danny Cluck, Forest Health Protection (FHP) Entomologist, visited the West Shore project on April 9 and August 20, 2018. The objective of these visits was to evaluate the current forest health conditions within the project area, discuss what influence these conditions would have on stand management objectives and provide recommendations as appropriate.

Key findings:

- Mixed conifer and ponderosa pine stands have become overstocked with a high percentage of white fir that is inhibiting the regeneration of shade intolerant pine species in many locations (Figure 1).
- White fir mortality increased dramatically in 2016 and 2017 across the entire project area.
- Heterobasidion root disease in white fir is creating numerous hazard trees within and adjacent to campgrounds, summer home tracts and recreation facilities.
- Bark beetle-caused mortality of ponderosa, Jeffrey and sugar pine also increased in high density stands during the recent drought.
- White pine blister rust is infecting sugar pine, increasing the susceptibility of mature trees to bark beetle attack and negatively impacting regeneration.
- Nearly all stands are at risk to moderate and high severity wildfire due to due crowded stand conditions and accumulating dead and down course woody debris from past bark beetle and root disease-caused tree mortality.
- Thinning and prescribed fire are highly recommended throughout the project area to reduce tree density and reduce surface and ladder fuels. All white fir in recreation areas should be carefully assessed for hazard due to widespread incidence of root disease. Specific recommendations are provided in this evaluation.

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Description of the project area

The West Shore project is located 8 miles southeast of the community of Chester, CA at elevations ranging between 4,500 and 5,800 feet (40.198551N and 121.164270W). It encompasses several campgrounds, summer home tracts, boat launches and day use recreation areas along the west shore of Lake Almanor. Annual precipitation ranges between approximately 30 and 40 inches. Most of the area is comprised of pine dominated sierra mixed conifer consisting of ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*Pinus jeffreyi*), sugar pine (*Pinus lambertiana*), white fir (*Abies concolor*), incense cedar (*Calocedrus decurrens*) and Douglas-fir (*Psuedotsuga menziesii*). Native ponderosa and Jeffrey pine stands are found at lower elevations and flats at the north end of the project area along with ponderosa and Jeffrey pine plantations. Small areas of fir dominated Sierra mixed conifer are found at upper elevations near the south end of the project area. Pockets of lodgepole pine (*Pinus contorta*) are found within lowland meadows and riparian corridors throughout the project area. In many of the mixed conifer areas, shade-intolerant pine species are mostly restricted to the overstory with limited regeneration due to overcrowding and dominance of white fir.

Figure 1. Ponderosa pine stand with dense white fir ingrowth in Almanor Campground North.

Project objectives

The West Shore project proposes to reduce the risk of insect and disease-caused tree mortality through mechanical and hand thinning. Fuels reduction and maintenance would also be accomplished with mastication and prescribed burning. White fir will be removed in favor of

retaining other tree species in mixed conifer and ponderosa pine stands. Residual stands will be more open, increasing the amount of available soil moisture and sunlight for individual trees. Openings created through thinning will facilitate natural and artificial regeneration of pine species. Hazard trees will also be removed within recreation and administrative sites.

Forest insect and disease conditions

Agents/hosts observed during site visits:

- Recent and current white fir mortality and top-kill caused by the fir engraver beetle (*Scolytus ventralis*) (Figure 2).
- Scattered individuals and small groups of ponderosa pine mortality caused by western pine beetle (*Dendroctonus brevicomis*) (Figure 3).
- Heterobasidion root disease (*Heterobasidion occidentalis,* formerly referred to as S-type annosus root disease) in white fir as indicated by the presence of conks, delaminated decay on the roots of windthrown snags, stunted leader growth of infected trees and recent top-kill and whole tree mortality associated with the fir engraver beetle (Figures 4 and 5).
- Recent mountain pine beetle (*Dendroctonus ponderosae*)-caused mortality of sugar pine and ponderosa pine.
- White pine blister rust (*Cronartium ribicola*) infections on sugar pine causing top-die back and bole deformities.
- Incense cedar rust (*Gymnosporangium libocedri*) on incense cedar in several locations.
- White fir dwarf mistletoe (*Arceuthobium abietinum f. sp. concoloris*) in portions of the project area in both overstory and understory white fir causing bole deformities on a few trees.
- Elytroderma disease (*Elytroderma deformans*) in Jeffrey and ponderosa pine causing branch and bole deformities.
- Indian paint fungus (*Echinodontium tinctorium*) causing decay in older white fir.
- Black stain root disease (*Leptographium wageneri*) infecting ponderosa pine in the Prattville plantation.
- Western gall rust (*Peridermium harknessii*) in ponderosa and lodgepole pine near the lakeshore and other low lying areas.

Figure 2. Dead top on white fir caused by fir engraver beetle.

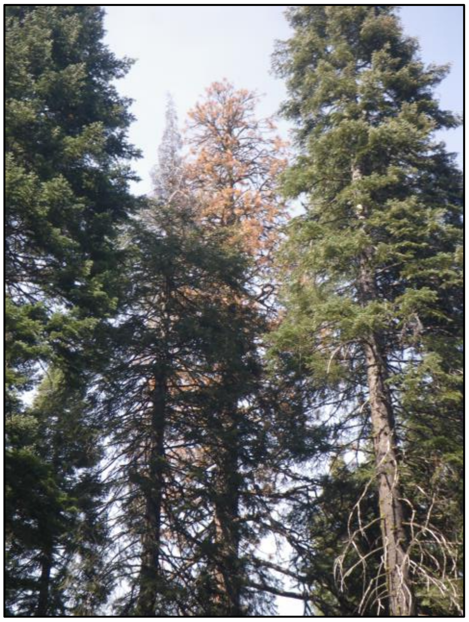


Figure 3. Legacy ponderosa pine killed by western pine beetle in Almanor Campground North.

Figure 4. Conk of *H. occidentale* in old white fir stump near amphitheater.

Figure 5. Hollowed out stump caused by *H. occidentale* infection in stand #15.

<u>Stand conditions and tree mortality related to recent and future climate trends</u>

Most forested areas in the West Shore project are overstocked and have experienced an elevated level of tree mortality caused by bark beetles, woodborers and disease in response to drought (Table 1 and Figures 6 - 8). Aerial detection surveys documented a large increase in mortality within the project area starting in 2016 and continuing into 2017. This mortality combined with the existing high stand density has resulted in heavy fuel loading in some areas and a corresponding increase in the risk of stand replacing wildfire.

Figure 6. Older ponderosa pine mortality between boat launch and Almanor Campground North.

Table 1. Acres with tree mortality, estimated dead trees per acre, estimated total # of dead trees from R5 Aerial Detection Surveys and Palmer Hydrologic Drought Index (PHDI) (CA Division 2) by water year (Oct-Sept) within the West Shore project.

Year	Acres	Dead Trees/Acre	Total # of Dead Trees	PHDI[1]
2017	1,644	3.1	5,107	2.45
2016	2,958	4.4	13,036	-1.78
2015	152	1.8	272	-3.03
2014	91	1.0	91	-3.12
2013	38	1.0	39	-1.62
2012	6	1.8	11	0.37
2011	5	1.8	9	2.59
2010	12	2.0	24	0.19
2009	21	1.4	29	-2.69
2008	7	1.3	9	-2.74

[1] Palmer drought values show a relationship to tree mortality. PHDI values ranging from -2.00 to -2.99 are considered moderate drought conditions. Severe drought conditions range from -3.00 to -3.99 and extreme drought conditions are below -4.00.

Figure 7. Cumulative dead trees per acre mapped by ADS between 2008 and 2017.

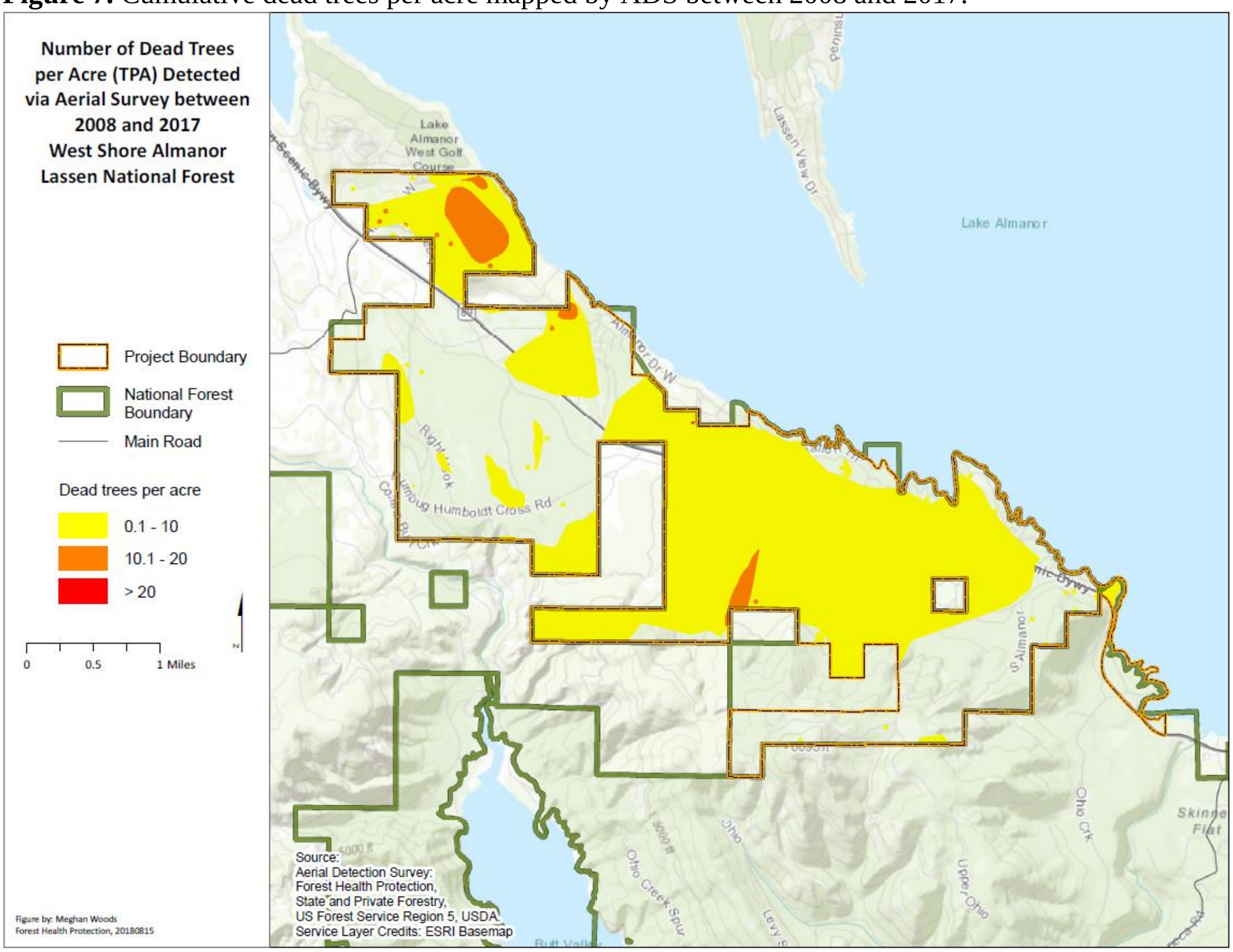
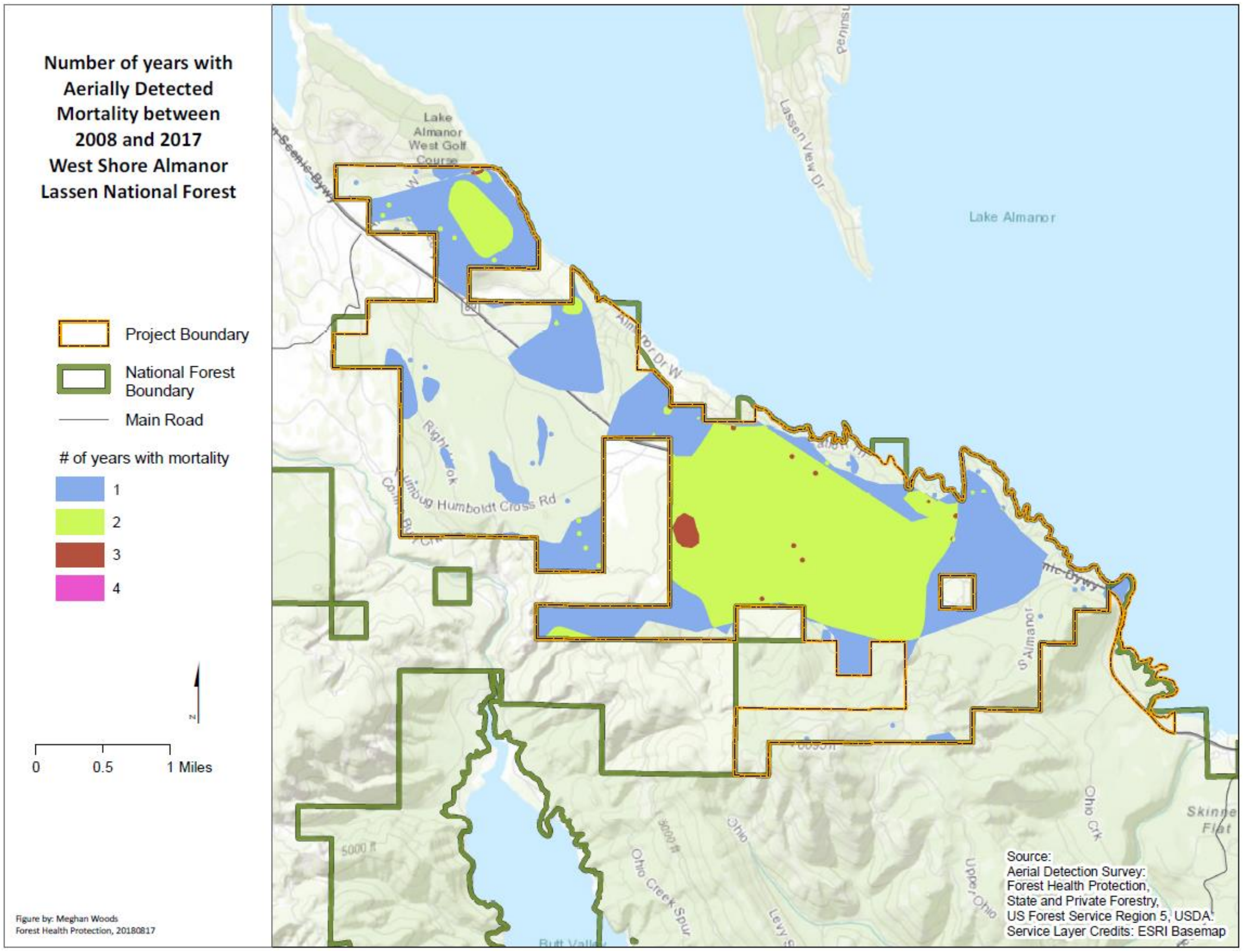


Figure 8. Number of years of tree mortality mapped by Aerial Detection Surveys (ADS) between 2008 and 2017.



Predicted climate change is likely to impact trees growing in this area over the next 100 years. Although no Lassen National Forest specific climate change models are available at this time, there is a general consensus among California models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (K. Merriam and H. Safford, *A summary of current trends and probable future trends in climate and climate-driven processes in the Sierra Cascade Province, including the Plumas, Modoc, and Lassen National Forests*). The risk of bark beetle-caused tree mortality will likely increase for all conifer species under this scenario, especially drought intolerant white fir with high levels of root disease. Improving the resilience of stands to future disturbance events through density, size class and species composition management will be critical to maintaining a healthy forested landscape.

Discussion and recommendations

Most of the West Shore project area has become very dense, with a corresponding increase in white fir, with the exclusion of fire over the past 100+ years. With such a high density of white fir in the area, more shade intolerant and fire resilient species such as ponderosa, sugar and Jeffrey pine have declined due to excessive competition for sunlight, water and nutrients. These are not resilient forest conditions and will likely lead to unacceptable levels of tree mortality from bark beetles and disease or high severity wildfire (Figure 9). West Shore plot data

(Danheiser 2018) shows that well over half the stands have a Stand Density Index (SDI) >350 which puts them above the lower limit of the zone of self-thinning for mixed conifer stands and very close to the zone (SDI >365) where bark beetle outbreaks are likely to occur in ponderosa pine stands (Oliver 1995). Many stands have a SDI >400 and a few exceed SDI 500.

Thinning treatments are recommended to improve forest health conditions and increase resiliency to disturbance. Treatments should aim to reduce stand density to a level that significantly lowers the risk of bark beetle-caused mortality. In most cases, thinning to a relative density of 25 - 40% (relative to the maximum Stand Density Index, or SDI) for a specific conifer species or for a weighted composition of conifer species will effectively reduce competition for limited water and nutrients and reduce the susceptibility to future bark beetle-caused tree mortality for many years. The District should consider an SDI max of 450 for drier mixed conifer (Long and Shaw 2005) on south facing slopes and ridge tops and SDI max 550 (Long and Shaw 2012) for mixed conifer on more mesic aspects and at higher elevations. The District should also consider reducing the SDI in ponderosa pine dominated stands to well below 230. SDI 230 is the defined threshold for the zone of imminent bark beetle caused mortality (Oliver 1995). Thinning stands to this level will reduce the risk of additional bark beetle-caused mortality by reducing tree competition for limited water and nutrients.

Figure 9. Dense mixed conifer with dead and down trees at north end of West Shore project.

Many stands contain large diameter ponderosa, Jeffrey and sugar pine competing with dense stands of white fir (Figure 10). Thinning treatments that improve growing conditions for these more shade intolerant species, such as removing a large percentage of the white fir basal area around these trees, would increase their health and vigor, create opportunities for their successful regeneration and improve overall resiliency to disturbance agents (insects, disease, drought and fire). Removing competing trees from the base of large diameter pines combined with stand level

Figure 10. Old growth ponderosa pine growing among very dense white fir in Almanor Campground South.

thinning has resulted in a measured increase in annual increment growth in old growth ponderosa and Jeffrey pine on the Lassen National Forest (Hood et al 2017).

When planning thinning treatments, it should be recognized that the target stand density is an average to be applied across the landscape and some variability may be desired. Individual high value trees, such as mature pines, should benefit by having the stocking around them reduced to lower levels. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as forked and/or broken-topped trees, or on more mesic north-facing slopes. Incorporating the concepts of GTR 220 will address many of these issues and be consistent with Regional ecosystem restoration goals. Many of these methods are also consistent with past FHP recommendations for thinning in mixed conifer stands and their use is supported for the West Shore project. These types of prescriptions would also be consistent with 2014 Farm Bill Section 602(d)(1) direction that allows the implementation of projects "….to reduce the risk or extent of, or increase the resilience to, insect or disease infestation in the areas." In addition to the above considerations, the District should favor the removal of trees that are heavily infected with dwarf mistletoe, Elytroderma needle cast, Indian paint fungus, western gall rust and trees that are infested with bark beetles. Incense cedar rust is generally not a management concern.

The presence of Heterobasidion root disease in white fir should be considered when developing silvicultural prescriptions. Root diseased true fir are at a higher risk for fir engraver attacks than uninfected trees during droughts. Leaving high numbers of root diseased trees in the overstory will likely lead to higher levels of mortality over the long-term, reducing canopy cover and increasing fuels (Figure 11). Heterobasidion infected true fir are also more likely to fail, creating a hazardous situation in recreation areas (Figure 12).

Figure 11. Fuels from recent hazard tree abatement of dead white fir, Almanor Campground North.

The best option for managing *H. occidentale* in white fir is to reduce its overall abundance in the stand and remove severely infected trees. Various sized openings can be created in the stand to facilitate planting of non-hosts such as ponderosa, Jeffrey and sugar pine. Placing these openings on known or suspected root disease pockets will enhance the effectiveness of this strategy for reducing overall infection levels. In addition, greatly reducing white fir stocking in stands that have a non-host overstory component will allow for natural non-host regeneration and create a more resilient species composition over time.

Figure 12. Numerous white fir stumps from ongoing mortality and hazard tree removal associated with *H. occidentale* infected white fir, Almanor Campground Ampitheather.

It is recommended that a registered borate compound be applied to all freshly cut conifer

stumps >14” in diameter to reduce the chance of creating new infection centers of *Heterobasidion irregulare* and *H. occidentale* formerly referred to as P-type and S-type annosus root disease, through harvest activity. An exception to this recommendation would be for white fir stumps in pine dominated mixed conifer stands or more pure white fir stands if there is already a high level of Heterobasidion root disease present as treating white fir stumps in heavily infected stands is ineffective. All conifer stumps greater than 3” in diameter must be treated with a registered borate compound (FSM R5 Supplement 2300-92-1 modified by FSH R5 Supplement 3409.11-2010-1) within areas such as campgrounds, day-use areas and other high-use areas such as parking lots and boat ramps.

Sugar pine should be retained as much as possible during any thinning operation in order to preserve genetic diversity, especially white pine blister rust (*Cronartium ribicola*) resistant individuals. An exception to this would be thinning suppressed trees within pure sugar pine groups to reduce inter-tree competition. White pine blister rust, a non-native pathogen, has continued to weaken and kill this species over most of its range since its introduction into the Pacific Northwest in 1910. Identification and protection of local rust resistant trees for seed collection, if not already occurring, will aid in the future planting of rust resistant seedlings. Planting selected openings created through thinning operations with rust resistant stock would help insure this species persists in the area.

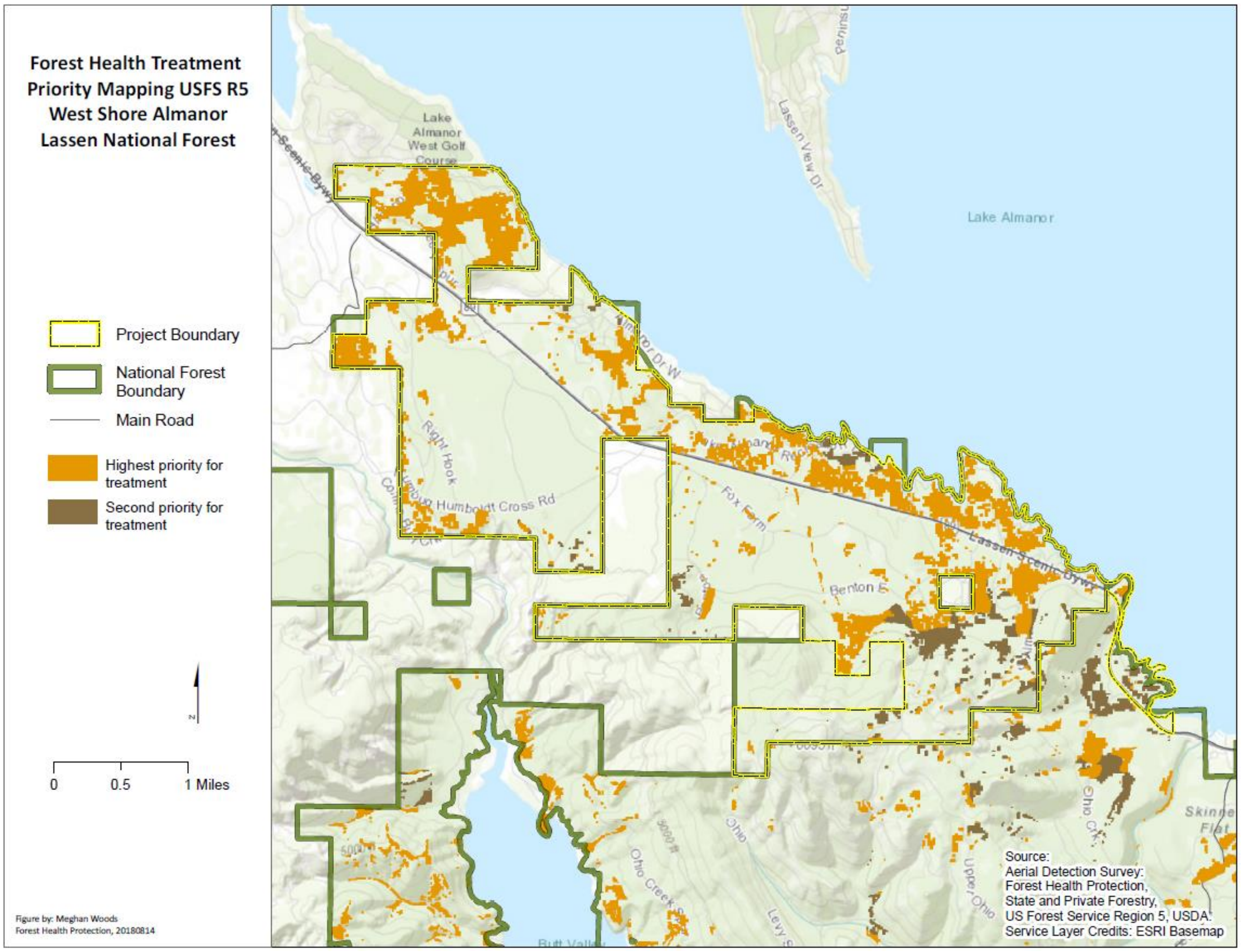
Black stain root disease is present within the Prattville ponderosa pine plantation as well as within a few native ponderosa and Jeffrey pine stands at the north end of the project area. Thinning to wider spacing, removing symptomatic trees and retaining non-host species where available is highly recommended in black stain pockets. In addition, planning for treatments to occur between late June and early September can minimize soil disturbance and avoid peak activity for insect vectors of the disease. More specific information and management actions for black stain root disease are found in Appendix A.

Forest Health Protection recently developed a treatment priority map for Region 5 to help land managers prioritize thinning treatments at the landscape level. This map depicts forested areas on National Forest System lands that are the most susceptible to drought and bark beetle-caused tree mortality based on forest type and stand density. These areas also meet the criteria of existing on slopes <=35% and being outside of wilderness areas, wild and scenic river corridors, designated roadless areas and California spotted owl protected activity centers. Additional criteria include not having burned at moderate to high severity since 1998 and not having been thinned since 2005. In addition to being overly dense, these areas have a history of tree mortality during drought resulting in heavy fuel loads and higher risk of stand replacing wildfire. Highest priority areas consist of high density pine stands, pine-dominated mixed conifer stands and fir-dominated mixed conifer and white fir stands growing on historically pine dominated sites. Second priority areas consist of high density fir-dominated mixed conifer and white fir stand on wetter sites. All mapped stands are California Wildlife Habitat Relationship size class 4, 5 and 6.

Figure 13 shows treatment priority areas within the West Shore project boundary. This mapping effort utilized remotely sensed data to create treatment priority layers for large scale planning and may not be accurate at the stand level. The forest should still use stand records and stand exam data to identify treatment areas and develop silvicultural prescriptions. An ALL LANDS version of the map was also created that includes wilderness areas, wild and scenic river corridors, designated roadless areas and California spotted owl protected activity centers to

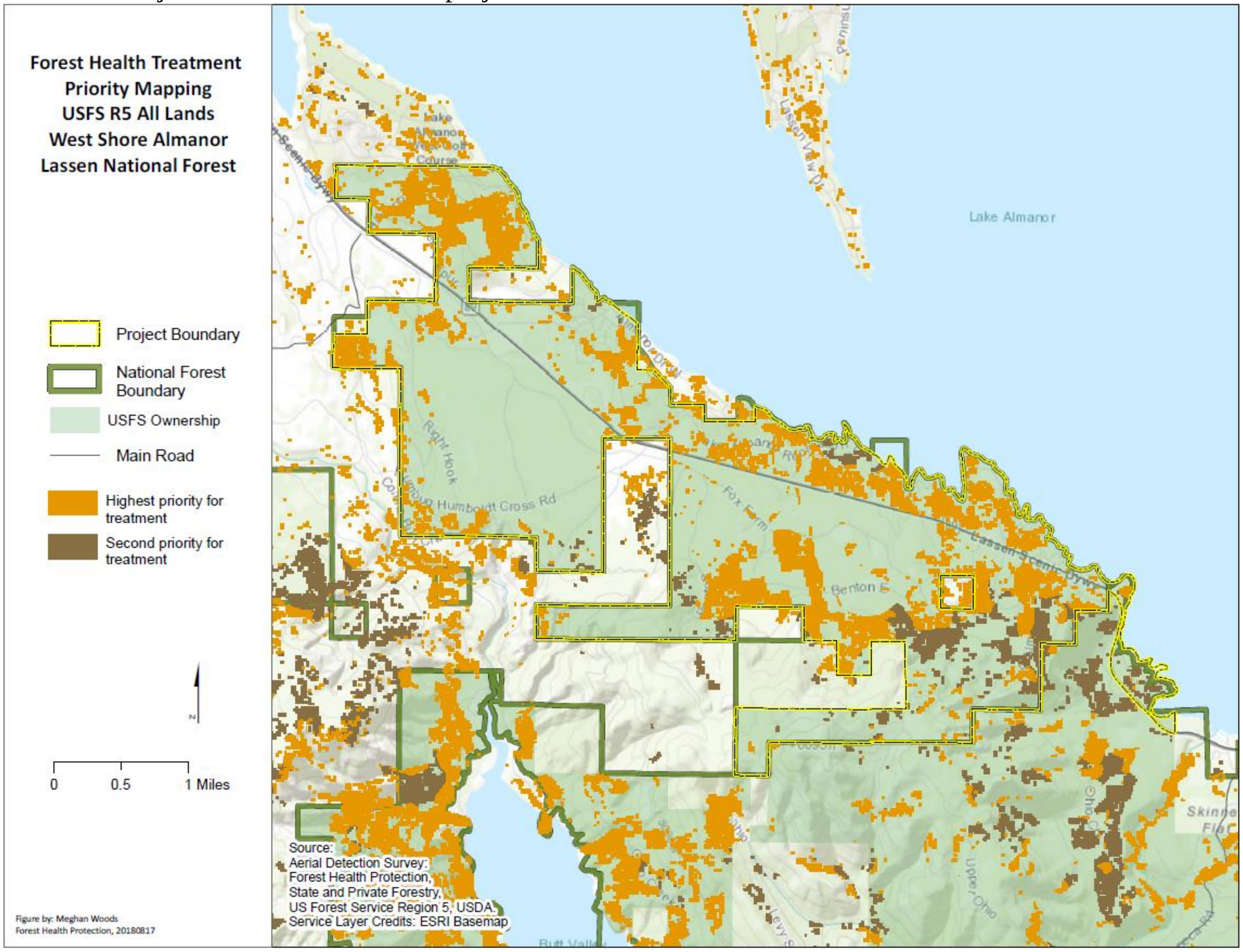
evaluate stand conditions in these protected areas. It also includes slopes >35% and all land ownerships (Figure 14).

Figure 13. Treatment Priority Areas* at risk to bark beetle-caused mortality within and adjacent to the West Shore project area



*Highest priority treatment areas include overly dense stands (>60% of maximum stand density index) of pine and pine-dominated mixed conifer stands as well as fir-dominated mixed conifer and white fir stands growing on historically pine-dominated sites. Second priority treatment areas include overly dense stands of fir-dominated mixed conifer and white fir. Mapped areas only include CWHR size class 4, 5 and 6 stands. Wilderness areas, inventoried roadless areas, wild and scenic areas, spotted owl protected activity centers, moderate to high severity burned areas since 1998, areas thinned since 2005, areas with >35% slope and all non-National Forest System lands were excluded from this analysis.

Figure 14. Treatment Priority Areas (ALL LANDS version)* at risk to bark beetle-caused mortality within and adjacent to the West Shore project area.



*Highest priority treatment areas for ALL LANDS version include overly dense stands (>60% of maximum stand density index) of pine and pine-dominated mixed conifer stands as well as fir-dominated mixed conifer and white fir stands growing on historically pine-dominated sites. Second priority treatment areas include overly dense stands of fir-dominated mixed conifer and white fir. Mapped areas only include CWHR size class 4, 5 and 6 stands. Moderate to high severity burned areas since 1998, areas thinned or that experienced stand replacing disturbance such as clear cuts or bark beetle-caused tree mortality since 2005 were excluded from this analysis.

Additional considerations for campgrounds

Trees within West Shore campgrounds, like most forested high-use recreation areas, are exposed to additional stress factors that can compromise their health and vigor. Firewood collecting sometimes leads to tree wounding from hatchets and saws. Carving and chopping trunks can cause extensive cambium damage (Figure 15). Foot and vehicle traffic compacts soil and can damage roots. Posting public information signs at campground entrances may help increase awareness of the human impact on campground trees.

Soil compaction can predispose conifers to bark beetle attacks and subsequent mortality. Compaction can reduce the water holding capacity of the soil and suffocate roots, which limits the available oxygen that is necessary for root growth and survival. Damaged and unhealthy roots cannot provide the upper portions of the tree with the water and nutrients it requires to maintain its natural defenses. Soil compaction and associated root injury are long-term problems

that may not reveal themselves until several years after the damage has occurred. In order to minimize future soil compaction and root damage, campers should be directed to specific travel corridors from campsites to restrooms, water sources, and specific recreation areas. It is especially important to divert and limit foot and vehicle travel and keep excavation for roads, trails and utilities away from the root zones of trees.

Figure 15. Human-caused injury to white fir in Almanor Campground North.

Considerations for hazard trees

Despite the effectiveness of any long or short-term plans to prevent tree injury and mortality, some trees, through declining health, will eventually become hazards to the public. To minimize risk, hazard trees should be identified and removed before they fail. The current practice for many National Forest campgrounds is to remove trees as they die. This eliminates the risk from dead trees but fails to address living trees that are infected with root disease, heart rot, and/or have a structural defect. These high-risk green trees are equally hazardous and should not be overlooked.

It is recommended that the District develop a hazard tree evaluation and monitoring plan for these recreation areas. Region 5 Forest Health Protection has recently developed hazard tree guidelines that can assist with this process (Angwin et al 2012). In the short-term, trees within the campgrounds, and within striking distance of a target, that have obvious stem decay, dead tops and/or large dead branches should be carefully evaluated and hazards removed or pruned as soon as possible. All standing dead trees within striking distance of any target should be removed immediately.

All white fir within recreation areas should be carefully evaluated for Heterobasidion root disease. Having the white fir component of the recreation area heavily impacted by Heterobasidion root disease is an extremely dangerous situation. Efforts should be made immediately to abate obvious hazard trees and plan for their replacement over the long-term with tree species that are not susceptible to *H. occidentale* (e.g. pines and incense cedar). In addition, stand density should be reduced, with an emphasis on retaining non-host species, to increase the health and vigor of individual trees. Where white fir are to be retained, younger trees, with healthy crowns, should be favored over older trees. However, leaving residual white fir will allow root disease to persist within the area, leading to more hazard trees over the long-term.

For Heterobasidion root disease, it is reasonable to use the condition of the crown as an indicator of advanced decay. Although not always caused by root decay, a thin crown does indicate poor tree vigor. A tree with reduced photosynthesis is not able to maintain healthy roots as well as a tree with a full and healthy crown. In the presence of root disease, unhealthy roots will likely be overcome with decay faster than vigorously growing roots. For this reason, the thinner the crown of a tree in an area where root disease is present, the more likely it is that the roots have been weakened by decay.

Considerations for Rx fire

If prescribed fire is used as a follow-up treatment to stand thinning, it may result in unacceptable levels of tree mortality; depending on management objectives. This mortality most often occurs as a direct result of cambium or crown injury to individual trees during the fire. Mature ponderosa, Jeffrey and especially sugar pines are susceptible to lethal basal cambium damage during prescribed burns from the heat that develops in the deep duff and litter that accumulates at their bases. These duff mounds typically burn at a slow rate with lethal temperatures, causing severe injury to the cambium which girdles the trees. To protect individual high-value large diameter pine and black oak from lethal cambium damage, raking the duff away from the bases of these trees before burning (within 24" of the bole and down to mineral soil) is recommended.

Potential for funding thought the Western Bark Beetle Program

Forest Health Protection may be able to assist with funding for thinning and removing green material from overstocked areas within the West Shore project area. Thinning treatments that reduce stand density sufficient to lower the risk to bark beetle-caused mortality would meet the minimum requirements for Western Bark Beetle Program funding and would be supported by this evaluation. If you are interested in this competitive funding please contact me for assistance in developing and submitting a proposal.

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-252-6431.

/s/ Danny Cluck

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Chris Obrien, Natural Resource Officer, Lassen SO
Forest Health Protection, Regional Office

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Appendix A: Insect and Disease Information

Western Pine Beetle

The western pine beetle, *Dendroctonus brevicomis*, has been intensivly studied and has proven to be an important factor in the ecology and management of ponderosa pine thoughout the range of the host species (Miller and Keen 1960). This insect breeds in the main bole of living ponderosa pine larger than about 8 inches DBH. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latidude and elevation, there can be from one to four generations per year.

Evidence of Attack

Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pitch tubes are formed on the tree trunk around the entry holes. Successful pitch tubes are red-brown masses of resin and boring dust. Relativly few, widely scattered white pitch tubes usually indicate that the attacks were not successful and that the tree should survive. Pheremones released during a successful attack attract other conspecifics. Attracted beetles may then spill over into nearby apparently healthy trees and overwhelm the tree with sheer numbers.

Life Stages and Development

These beetles pass thorugh the egg, larval, pupal and adult stages during a life cycle that varies in length dependent primarily on temperature. Adults bore a sinuous gallery pattern in the phloem and the female lays eggs in niches along the sides of the gallery. The larvae are small white grubs that first feed in the phloem then mine into the middle bark where they complete most of their development. Bluestain fungi inoculates the tree during successful attacks, blocking trachids and vessicles which contribute to the rapid tree mortality associated with bark beetle attacks.

Conditions affecting Outbreaks

Outbreaks of western pine beetle have been observed, and surveys made, in pine regions of the Westsince 1899 (Hopkins 1899; cited in Miller and Keen 1960). An insect survey completed in 1917 in northern California indicated that over 25 million board feet of pine timber had been killed by bark beetles.Information from surveys conducted in the 1930's indicated enormous losses attributed to the western pine beetle around that time. During the 1930's outbreak, most of the mortality occurred in stands of mature or overmature trees of poor vigor (Miller and Keen 1960). Group kills do not typically continue to increase in size though successive beetle generation as is typical with Mountain Pine Beetle and Jeffreay Pine Beetle. Rather, observations indicate that emerging beetles tend to leave the group kill area to initiate new attacks elsewhere.

The availability of suitable host material is a key condition influencing western pine beetle outbreaks. In northeastern California, drought stress may be the key condition influencing western pine beetle outbreaks. When healthy trees undergo a sudden and sever moisture stress populations of western pine beetle are likely to increase. Healthy trees ordinarily produce abundant resin, which pitch out attacking beetles, but when deprived of moisture, stressed trees cannot produce sufficient resin to resist the attack. Any condition that results in excessive demand for moisture, such as inter-tree

completion, competing vegetation, or protracted drought periods; or any condition that reduces the ability of the roots to supply water to the tree, such as mechanical damage, root disease or soil compaction, can cause moisture stress and increase susceptibility to attack by the western pine beetle. Woodpeckers, predacious beetles, and low temperatures act as natural control agents when beetle populations are low (endemic populations).

Fir Engraver

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater that 4" in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack

Fir engravers bore entrance holes along the main stem, usually in areas that are > 4" in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development

In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year, however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

Mountain pine beetle

The mountain pine beetle, *Dendroctonus ponderosae,* attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 8 inches dbh. Extensive infestations have occurred in mature lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

Evidence of Attack

The first sign of beetle-caused mortality is generally discolored foliage. The mountain pine beetle begins attacking most pine species on the lower 15 feet of the bole. Examination of infested trees usually reveals the presence of pitch tubes. Pitch tubes on successfully infested trees are pink to dark red masses of resin mixed with boring dust. Creamy, white pitch tubes indicate that the tree was able to "pitch out" the beetle and the attack was not successful. In addition to pitch tubes, successfully infested trees will have dry boring dust in the bark crevices and around the base of the tree. Attacking beetles carry the spores of blue-staining fungi which develop and spread throughout the sapwood interrupting the flow of water to the crown. The fungi also reduces the flow of pitch in the tree, thus aiding the beetles in overcoming the tree. The combined action of both beetles and fungi causes the needles to discolor and the tree to die.

Life Stages and Development

The beetle develops through four stages: egg, larva, pupa and adult. The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is typical, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine. Females making their first attacks release aggregating pheromones. These pheromones attract males and other females until a mass attack overcomes the tree. The adults bore long, vertical, egg galleries and lay eggs in niches along the sides of the gallery. The larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

Conditions Affecting Outbreaks

The food supply regulates populations of the beetle. In lodgepole pine, it appears that the beetles select larger trees with thick phloem, however the relationship between beetle populations and phloem thickness in other hosts has not been established. A copious pitch flow from the pines can prevent successful attack. The number of beetles, the characteristics of the tree, and the weather affect the tree's ability to produce enough resin to resist attack. Other factors affecting the abundance of the mountain pine beetle include nematodes, woodpeckers, and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and pine mortality increases.

Heterobasidion Root Disease

Heterobasidion spp. is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease

include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species: *Heterobasidion occidentale* (also called the 'S' type) and *H. irregulare* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregulare* (‘P’ type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentale* (‘S’ type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentale* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

Dwarf mistletoe

Dwarf mistletoes (*Arceuthobium* spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occassionaly vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been

measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

White pine blister rust

White pine blister rust is caused by *Cronartium ribicola* an obligate parasite that attacks 5-needled pines and several species of *Ribes* spp. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on *Ribes* spp. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to *Ribes* spp. where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other *Ribes* spp. throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on *Ribes* spp. leaves in the fall. Teliospores germinate in place to produce spores (sporida) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to *Ribes* spp. to continue the cycle. Although blister rust may spread hundreds of miles from pines to *Ribes* spp., its spread from *Ribes* spp. back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers that have margins more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.

Black stain root disease

Hosts: Ponderosa and Jeffrey pine, pinyon pine, and Douglas-fir. Lodgepole pine, western hemlock, mountain hemlock, sugar pine and knobcone pine are also susceptible, but damage is rare.

Characteristics: There are three distinct taxonomic varieties (subspecies) of the black stain root disease pathogen. Each variety has a unique set of hosts, and all are found in California. *Leptographium wageneri* var. *wageneri* is pathogenic to pinyon pine; *L. wageneri* var. *pseudotsugae* causes black stain root disease in Douglas-fir; and *L. wageneri* var. *ponderosum* attacks ponderosa, Jeffrey and lodgepole pine, and occasionally sugar pine and hemlock. Black stain root disease is a vascular wilt disease. It kills trees by blocking their water conducting vessels, and can cause substantial mortality. It does not cause decay of root or stem tissue. Colonization of the root system causes a visible decline in the tree crown. Terminal growth is reduced, needles become shorter and chlorotic, the number of needles produced and retained is reduced (“lion’s tail” appearance of branches), and finally the host dies. Disease centers appear as small (usually less than 0.04 ha or 0.1-ac) groups of dead and symptomatic trees. Infection centers

can sometimes be much larger, especially in ponderosa pine stands. Unless also affected by root rot fungi, trees killed by black stain root disease usually remain standing. Typical infection centers have trees in various stages of decline near the perimeter and dead trees in the interior where infection originated. Trees with black stain root disease are frequently predisposed to bark beetle infestation.

Symptoms and Signs: Black stain root disease is relatively easy to identify in the field. It produces a distinctive dark brown to black sapwood stain in the roots and root crown that sometimes streaks upward into the lower bole. Cross sections of the wood reveal the stain to be in arcs that follow the annual rings. This stain differs from blue stain, which is more bluish, wedge-shaped in cross section, follows the rays, and is associated with beetle galleries throughout the tree. In black stain-infected overstocked pole sized ponderosa or Jeffrey pine stands or understories, a common symptom is numerous haphazardly fallen stems laying in a ‘jack-strawed’ manner.

Disease Cycle: Infection centers may be initiated by root-feeding bark beetles and weevils that carry fungal spores on their bodies. These insects are attracted to wounds, the roots of fresh stumps, and weakened, low-vigor trees, which may account for the common association of the disease with disturbances. Infection of pines appears to be favored by wet, cool environments. Local tree-to-tree spread is via infection of small rootlets, following either root contact or short distance growth of the fungus through soil. Disease centers can enlarge at a rate of four to twelve feet per year. Although the fungus can remain for long periods in live host tissue, it is relatively nonpersistent and is difficult to isolate from previously infected wood much more than a year after the tree dies.

Damage and Importance: Black stain root disease usually is found in areas where there has been significant site disturbance or substantial amounts of tree injury, especially in stands after precommercial thinning, along roads, skid trails and landings, on sites with drought-stressed, waterlogged, or compacted soils, or where rotary blade brush cutters have been used to clear roadsides. Certain characteristics are related to black stain root disease in ponderosa pine in the central Sierra. Stands are usually densely stocked and consist of either pure or predominantly ponderosa pine. The largest and most rapidly expanding disease centers are often in cool, low lying sites with high soil moisture levels in the spring. In recent years, black stain root disease has been detected in many new areas, often causing locally severe damage. Incidence appears to be steadily increasing. While the disease is common in cool, wet, overstocked and disturbed sites, bark beetle-caused mortality of trees that are weakened by *L. wageneri* can likewise be significant during periods of drought and other stress.

Management Strategies: At the present time, there is no effective cure for trees that are already infected, and genetically resistant host genotypes have not been identified. Indications from the few long-term field studies that have been conducted suggest that disease impacts may be minimized by maintaining trees in a vigorous condition with adequate spacing while avoiding disturbance and injury, especially during times of peak beetle activity. Partial cutting to attain these objectives can increase or decrease black stain root disease incidence in a stand, depending on several factors, including the amount of soil disturbance that occurs; the time of year that the partial cutting is performed; the amount of host-to-host root contact that remains; and the amount of damage inflicted on residual trees. Several management actions have been suggested to reduce

the establishment of new infections and minimize the effects of the disease where it is already present:

- When establishing new stands in or near areas where black stain has been a management concern, a mix of species should be planted to provide future options for species manipulation.

- When thinning, thin aggressively during each entry, leaving an understocked stand. This will reduce the frequency of harvest entries and associated soil disturbance. Reduced stocking may contribute to disease resilience in a stand because uncrowded trees are more vigorous and less attractive to insect vectors of *L. wageneri* and other bark beetles. Open stands will also have warmer soils that inhibit *L. wageneri* and fewer root contacts between susceptible trees.

- Thin stands as early in the rotation as possible.

- During thinning, favor tree species that are resistant or immune to the locally important variant of *L. wageneri* and remove diseased or weakened trees.

- Whenever possible, leave trees that are not hosts for black stain root disease.

- When host tree species have been removed from an infection center, wait at least two years before replacing with host species.

- Harvest in a manner that minimizes soil disturbance and injury to the roots and boles of residual trees. Sites with soils that are prone to compaction by heavy equipment should not be tractor logged. Where timber harvest occurs, high-lead and skyline yarding would be preferred over tractor logging. If tractor logging is the only option, skid trails should be designated, the area covered by skid roads should be minimized, tree falling should be done to the yarding lead, and yarding should be restricted to the dry season when the risk of serious compaction is reduced. New road construction through high risk areas should be avoided. If construction occurs or old-roads must be re-opened, injured trees or those covered by side-cast fill should be removed. Efforts should be made to avoid injuring trees to be retained on site. This should preclude the use of rotary-blade brush cutters on roads adjacent to high risk areas.

- If possible, thin when insect vectors are least active, generally from late June to early September, allowing time for roots to dry out by fall. In areas where summer months are dry and droughty, the thinning period may be extended into late September. Late fall thins are not recommended because stumps may still attract insect vectors the following spring.

- Reintroduce frequent low intensity ground fires into the landscape. This will prevent ingrowth of brush or conifers which can stress host trees and create host-to-host root contacts. Monitor post-harvest black stain root disease activity to evaluate the effectiveness of various levels of thinning.